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ANALYSIS OF IGNITION IN A BOMB

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16. Abstract

A series of explosive firings with different powder compositions (B, GX and UG), different temperatures (+20, -20 and 51C), and different pyrotechnical compositions (PN, Zr/PbCr04, Al/KCl04, and Al/CuO) were analyzed. Based on measurements of the pressure development, the powder consumption law is derived, and the temperature behavior is studied. No clear relation between ignition composition and the temperature behavior of the powder was demonstrated by the results, though more scattered results were found for the standard composition than for Al/CuO and PN.

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ANALYSIS OF IGNITION IN A BOMB

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M. Fontenille*

SUMMARY. The EFAB, together with the DCP, has conducted a number of tests in order to determine the influence of the pyrotechnic priming composition on temperature behavior.

The results obtained show a slight sensitivity of this behavior for the compositions tested.

1. Presentation

Modern ammunition has to deliver high performance. For this purpose, various components of the propulsive charge have to be optimized globally. In particular, the powder and the igniter have to be given particular attention. In effect, it has been found that the velocity/pressure behavior of the ammunition was extremely sensitive to this pair of parameters.

The DCP and the ETBS, at the request of the EFAB, performed a series of bomb firings with powders B, GX and UG at various temperatures and for various ignition compositions. The purpose of these tests was to determine whether it would be possible to isolate within a bomb the influence on temperature behavior of the pyrotechnic ignition powder/composition parameter pair.

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Ignition was performed using powder containers filled with the pyrotechnic composition (Appendix 1).

The compositions used were:

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**Numbers in margin indicate pagination of foreign text.

$Zr/PbCrO_4$
$Al/KClO_4$
Al/CuO

P. N. fine + lignite.

The tests were performed at temperatures of +20, -20 and +51°C. For each triplet (powder, composition, temperature) two firings were made.

APPENDIX 1

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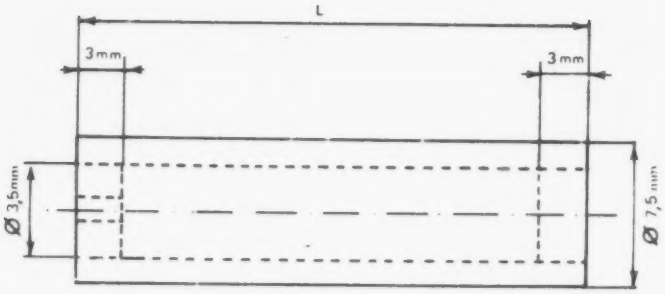

Composition	L	Masse l
PN	48 mm	2 g
$ZrPbCrO_4$	38 mm	2,2 g
$AlKClO_4$	35 mm	1 g
AlCuO	40 mm	1,6 g

l--mass

2. Analysis

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Firing in a bomb is characterized by the development of a pressure P(t) which is recorded. From this measurement one can derive the powder consumption law Z(t). By differentiation, one can define the linear consumption fine rate product function $\phi(3) \times \psi(P)$.

The knowledge of the rate law or the shape function is necessary to determine the other law.

In the range $Z \in \{0,1 ; 0,6\}$ we will assume that we have approximated $\phi(3)$ by a law $f_K(3)$ of the type $\sqrt{1-Kz}$. And, for corresponding pressures, the law $\psi(P)$ has been approximated by a law gn(P)of the type AP^n.

Therefore, we can determine, from a measurement P(t) a relationship n(K) which minimizes the spread between the calculated and the measured value.

Since we are interested in the temperature behavior, we will study the evolution of this relationship.

In Appendix 2 we show the analysis program of the test results.

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Analysis program

NOTE: The polynomial subprogram and the utility subprogram of HP determines the polynomial Y = P(x) of a degree which minimizes the sum of the squares of the deviations between the N calculated values (P(xi) and the measured values Yi.

```
10    OVERLAP
20    OPTION BASE 1
30    DIM E(200),Z(200),Dz(200),Se(200),Ar(4),Lp(200),Ldr(200),P(200),T(200)
40    INTEGER A,Hpres,Pas,Hperf
60    DIM A$[25000]
70    INPUT "N° DE LA PISTE (0 OU 1)",A
80    IF (A=0) OR (A=1) THEN GOTO 110
90    DISP "Improper track number -- ";
100   GOTO 70
110   PRINTER IS 0
120   PRINT LIN 1,"TRACK ";A;
130   INPUT "Enter file number.",B
140   B=ABS(B)
150   PRINT ,"FILE  ";B
160   A$=""
170   TREAD A,B,A$,E,F
180   Hp0=0
190   Hp10=6
200   Hp1=1000
210   Hp1=200
220   Hpa=Hp1
230   FOR I=5 TO LEN(A$)/2
240     IF Hpa Hp1 THEN Hpa=Hp1
250     IF I>Hpa+1000 THEN GOTO N1
260     P=256*NUM(A$[2*I-1])+NUM(A$[2*I])
270     IF (P 6000) OR (P 1) THEN Hp0=I
280     IF (P 6000) OR (P 1) THEN GOTO N1
290     IF (NUM(A$[2*I-1])=NUM(A$[2*Hpa-1])) AND (NUM(A$[2*I])=NUM(A$[2*Hpa])) 0
0 (NUM(A$[2*I-1]) NUM(A$[2*Hpa-1])) THEN Hpa=I
300     IF (P =10) AND (NUM(A$[2*I-3])=0) AND (NUM(A$[2*I-2])=10) THEN Hp10=I
310 N1:NEXT I
320   Pas1=(Hp10-Hp0)/50
330   Pas2=(Hpa-Hp10)/150
340   W=1
350   FOR I=Hp0 TO Hp10-1 STEP INT(Pas1)
360     T(W)=I 2E4
370     P(W)=(256*NUM(A$[2*I-1])+NUM(A$[2*I]))*1E5
380     W=W+1
390   NEXT I
400   FOR I=Hp10 TO Hpa STEP INT(Pas2)
410     P(W)=(256*NUM(A$[2*I-1])+NUM(A$[2*I]))*1E5
420     T(W)=I 2E4
430     W=W+1
440   NEXT I
450   N=W-1
460   REDIM P(N),T(N)
```

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```
470   REDIM Dz(N-1),Da(N-1),Lp(N-1),Lda(N-1)
480   Paa=P(N)
490   PRINTER IS 0
500   PRINT LIN(2),"PRESSION MAXIMALE :";Paa,LIN(1),"Temps D allumage";T 1
510   '
520   ' ACQUISITION DES CARACTERISTIQUES DU TIR
530   '
540 Param:  '
550   PRINTER IS 0
560   Eta=1E-3                                    ",Eta
570   INPUT "COVOLUME EN M^3                      ",Eta
580   PRINT "COVOLUME EN M^3
590   Delta=1600  "
600   INPUT "DENSITE EN Kg/M^3                    ",Delta
610   PRINT "DENSITE EN Kg/M^3
620   C=7E-4
630   INPUT "VOLUME DE LA BOMBE EN M^3            ",C
640   PRINT "VOLUME DE LA BOMBE EN M^3                  ",C
650   M=.140
660   INPUT "MASSE DE POUDRE EN Kg                ",M
670   PRINT "MASSE DE POUDRE EN Kg                ",M
680   Ma=3E-3
690   INPUT "MASSE DE COMPOSITION L AMORCE EN Kg   ",Ma
700   PRINT "MASSE DE COMPOSITION L AMORCE EN Kg   ",Ma
710   P0=1E5
720   INPUT "PRESSION DE L AMORCE EN Pa (100 000.CLASSIQUEMENT)",P0
730   PRINT "PRESSION DE L'AMORCE EN Pa (100 000.CLASSIQUEMENT)",P0
740   '
750   ' CALCUL DES CARACTERISTIQUES DE LA POUDRE
760   '
770   F=(Paa-P0)*(C-M*Ma*Eta)/M*Ma
780   PRINT LIN(1),"      F=";F,PAGE
790   GCLEAR
800   '
810   ' CALCUL DE Z(T)
820   '
830   FOR I=1 TO N
840     Z(I)=(P(I)-P0)*(C-M*Ma*Delta)/(P(I)*(P(I)-P0)*Eta+1-Delta*M*Ma
850   NEXT I
860   '
870   ' CALCUL DE DZ DT
880   '
890   FOR I=1 TO N-1
900     Dz(I)=(Z(I+1)-Z(I))/(T(I+1)-T(I))
910   NEXT I
920   '
930   ' ENTREE DES CARACTERISTIQUES DE L E PLOITATION
940   '
950   INPUT "Z1,Z2",Z1,Z2
960   INPUT "VALEUR DE I min ET ma  ET DU Pas",Imin,Imax,Ipas
970   FOR I=Imin TO Imax  STEP Ipas
980     PRINTER IS 0
990     PRINT LIN(2),"I= ";I
1000    PRINTER IS 16
1010  '
1020  ' CALCUL DE DP DE DT
1030  '
1040    ON ERROR GOTO 1070
1050    FOR I=1 TO N-1
1060      Da(I)=Dz(I)*SQR(1+(Z(I)*Z(I+1))^2)
1070    NEXT I
1080  '
1090  ' CALCUL DE LOG(F) ET DE LOG(DE DT)
1100  '
1110    ON ERROR GOTO 1150
1120    FOR I=1 TO N-1
1130      Lp(I)=LOG(P(I)-P(I+1))
1140      Lda(I)=LOG(Da(I))
1150    NEXT I
1160    OFF ERROR
1170  '
1180  ' TRACE DE LOG..LOG
1190  '
1200    MOVE 0,0
1210    SCALE 10,20,0,6
1220    GRID 2,2
1230    FOR I=1 TO N-1
1240      PLOT Lp(I),Lda(I)
```

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```
1250      GRAPHICS
1260    NEXT I
1270    PRINTER IS 0
1280    !
1290    !  CALCUL DE N-1
1300    !
1310    MAT A=ZER(4)
1320    Deg=1
1330    I1=N
1340    I2=0
1350    FOR I=1 TO N-1
1360      IF Z(I)<Z1 THEN Fin1
1370      IF Z(I)>Z2 THEN Fin
1380      I1=MIN(I1,I)
1390      I2=MAX(I2,I)
1400      GOTO Fin
1410 Fin1:I1=N
1420 Fin:NEXT I
1430    FOR I=1 TO I2-I1+1
1440      Z1(I)=Lp(I1+I-1)
1450      E1(I)=Ld(I1+I-1)
1460    NEXT I
1470    PRINT "Z1,Z2 = ";Z1;Z2
1480    CALL Polynomial(Z1(*),E1(*),I2-I1+1,Deg,A(*),Pages,Passs,Totalss,Pages,P
assm,F,Dfrag,Dfres,Dfrot,Abort)
1490    REDIM A(4)
1500    !
1510    ! IMPRESSION DES CARACTERISTIQUES APRES LISSAGE
1520    !
1530    PRINTER IS 0
1540    PRINT "N=";A(2),"B=";A(1),LIN(3)
1550    PRINTER IS 16
1560    MOVE Lp(I1),A(1)+A(2)*Lp(1)
1570    FOR I=I1 TO I2
1580      PLOT Lp(I),A(1)+A(2)*Lp(I)
1590      GRAPHICS
1600    NEXT I
1610    MOVE 0,0
1620  NEXT I
1630  !
1640  ! BOUCLAGE
1650  !
1660  GOTO 920
1670  STOP
1680  !
1690  !
1700  !
1710  !
1720  !
1730  !
1740  !
1750  SUB Polynomial(Xm(*),Ym(*),N,Degree,Coeffs(*),Pages,Passs,Totalss,Pages,Pass
s,F,Dfrag,Dfres,Dfrot,Abort)
```

```
 70  input "track number (8 or 1), A
520  acquisition of firing characteristics
570  covolume in
600  density in
630  volume of the bomb in
640  volume of the bomb in
660  input "powder mass" in  kg
690  composition mass of priming in  kg
720  priming pressure in Pa
750  calculation of powder characteristics
930  beginning of analysis characteristics (calcul = calculation)
1510 printout of characteristics after smoothing
1640 loop
```

3. The results /295

Results obtained are shown in Appendix 3.

This does not allow one to show the behavior difference of the relationship n(K), which is a function of temperature for the various tested powders and compositions.

Nevertheless, it seems that the standard priming agents gives results which are more widely dispersed than the igniters AlCuO and PN.

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In order to compare the igniters and in particular the ignition quality of a powder-igniter pair, it would be necessary to make a larger number of firings so as to be able to compare the standard deviations of these results with conpetence.

4. Conclusion

We have been able to show a possible influence of ignition composition on the temperature behavior of the powder.

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APPENDIX 3

Tables of results

Powder B

standard igniter

Reheating firings

Température /	-1	0	K 2	3	5
+51	1,04 1,05 1,0- 1,07	0,842 0,838 0,834 0,861	0,676 0,669 0,666 0,692	0,631 0,624 0,620 0 647	0,571 0,564 0,560 0,587
+20	0,996 1,04 1,012 1,06 1,05	0,795 0,835 0,811 0,858 0,841	0,629 0,668 0,643 0,692 0,671	0,583 0,623 0,598 0,646 0,626	0,524 0,563 0,538 0,587 0,566
-20	1,04 1,04 1,10	0,833 0,835 0,897	0,665 0,665 0,730	0,620 0,620 0,686	0,560 0,560 0,625

1--temperature

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POWDER B

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Allumeur /	température	K -1	0	2	3	5
$ZrPbCrO_4$	+51	1,06	0,850	0,681	0,636	0,576
		1,03	0,822	0,632	0,606	0,547
	+20	1,03	0,822	0,652	0,606	0,546
		1,02	0,824	0,657	0,612	0,552
	-20	1,04	0,831	0,663	0,617	0,558
		1,02	0,808	0,637	0,592	0,532
$AlKClO_4$	+51	1,02	0,811	0,624	0,597	0,537
		1,04	0,829	0,660	0,614	0,555
	+20	1,08	0,870	0,700	0,654	0,595
		1,03	0,819	0,645	0,603	0,543
	-20	1,01	0,807	0,638	0,592	0,532
		1,03	0,815	0,645	0,600	0,539
AlCuO	+51	1,02	0,817	0,650	0,604	0,544
		1,03	0,905	0,653	0,607	0,547
	+20	1,02	0,808	0,640	0,595	0,535
		1,02	0,813	0,643	0,597	0,537
	-20	1,05	0,843	0,674	0,628	0,569
		1,03	0,823	0,655	0,610	0,550
PN fine + lignite	+51	1,03	0,829	0,663	0,618	0,558
		1,04	0,835	0,666	0,621	0,562
	+20	1,06	0,843	0,673	0,627	0,568
		1,04	0,830	0,661	0,616	0,556
	-20	1,06	0,851	0,681	0,635	0,576
		1,06	0,847	0,675	0,630	0,571

1--igniter;

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POWDER GX

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Allumeur 1	température	K -1	0	2	3	5
$ZrPtCrO_4$	+51	1,05	0,846	0,677	0,632	0,572
		1,08	0,885	0,718	0,673	0,614
	+20	1,07	0,862	0,695	0,650	0,590
		1,06	0,858	0,693	0,648	0,588
	-20	1,13	0,922	0,754	0,709	0,649
		1,09	0,882	0,714	0,669	0,609
$AlKClO_4$	+51	1,10	0,897	0,732	0,687	0,627
		1,06	0,855	0,867	0,642	0,582
	+20	1,07	0,869	0,703	0,658	0,598
		1,07	0,863	0,695	0,650	0,590
	-20	1,09	0,891	0,725	0,680	0,620
		1,09	0,886	0,719	0,674	0,614
AlCuO	+51	1,06	0,859	0,692	0,647	0,587
		1,09	0,886	0,720	0,675	0,615
	+20	1,07	0,868	0,703	0,658	0,595
		1,07	0,862	0,692	0,647	0,587
	-20	1,09	0,886	0,718	0,673	0,613
		1,09	0,883	0,716	0,670	0,611
PN fine + lignite	+51	1,09	0,888	0,722	0,676	0,617
		1,11	0,911	0,743	0,698	0,638
	+20	1,11	0,906	0,740	0,695	0,635
		1,08	0,878	0,712	0,667	0,607
	-20	1,10	0,897	0,729	0,656	0,596
		1,09	0,883	0,716	0,671	0,611

1--igniter

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POWDER UG

/300

Allumeur /	température	K -1	0	2	3	5
$ZrPbCrO_4$	+51	0,977	0,762	0,591	0,546	0,486
		0,980	0,767	0,597	0,551	0,491
	+20	0,931	0,722	0,551	0,506	0,446
		1,01	0,790	0,614	0,568	0,508
	-20	0,918	0,710	0,542	0,497	0,437
		0,922	0,708	0,536	0,490	0,430
$AlKClO_4$	+51	1,02	0,818	0,650	0,605	0,545
		1,02	0,809	0,640	0,595	0,535
	+20	0,954	0,743	0,573	0,527	0,468
		0,937	0,732	0,563	0,517	0,457
	-20	0,932	0,710	0,534	0,488	0,428
		0,933	0,723	0,553	0,508	0,448
AlCuO	+51	0,970	0,763	0,594	0,549	0,489
		0,969	0,762	0,593	0,547	0,487
	+20	0,939	0,725	0,554	0,509	0,449
		0,934	0,724	0,554	0,509	0,449
	-20	0,95	0,736	0,565	0,519	0,459
		0,939	0,730	0,561	0,516	0,456
PN fine + lignite	+51	0,987	0,784	0,616	0,571	0,511
		1	0,787	0,616	0,570	0,510
	+20	0,958	0,745	0,575	0,530	0,470
		0,949	0,745	0,576	0,531	0,471
	-20	0,965	0,739	0,565	0,519	0,459
		0,959	0,741	0,589	0,523	0,464

1--igniter